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Standards and Guidelines

For

CADASTRAL SURVEYS

Using

Global Positioning System Methods

May 9, 2001
Version 1.0

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Foreword

These Standards and Guidelines provide guidance to the Government cadastral surveyor and other land surveyors in the use of Global Positioning System (GPS) technology to perform Public Land Survey System (PLSS) surveys of the Public Lands of the United States of America.

Many sources were consulted during the preparation of this document. These sources included other GPS survey standards and guidelines, technical reports and manuals. Opinions and reviews were also sought from public and private Professional Land Surveyors who use GPS for boundary and cadastral surveys.

The static and fast static survey procedures in these guidelines follow long established and well-documented industry and government survey practices. However, guidelines for real-time kinematic surveys of all types are in the early stages of development.

Manufacturer's technical manuals describe real-time kinematic GPS surveys as a topographic surveying method for small areas, not intended for surveying legal land boundaries nor for large project areas. Therefore, guidelines for performing land surveys using real-time kinematic GPS techniques require greater observational and occupational redundancies and checks than specified by the manufacturers.

These standards and guidelines do not require that cadastral surveys be performed to the higher accuracy and methodology requirements of geodetic control surveys. They are intended to provide sufficient observational and occupational redundancy to detect blunders and quantitatively demonstrate the stated accuracy of a survey has been achieved.

Cadastral Surveys are an important part of the National Spatial Data Infrastructure. The accuracy reporting requirements of this document is in accordance with accuracy reporting requirements of the Federal Geographic Data Committee's "Geospatial Positioning Accuracy Standards", July 1997.

Disclaimer Statement

This document is intended only for the purpose of providing the user with guidelines for planning, execution, and classification of PLSS surveys performed using GPS carrier phase methodology.

Note: Italicized words in bold font, i.e., ***independent occupation,*** indicate that a definition for that word appears in Appendix A: Definitions.

Part One

Standards for Positional Accuracy

The following standards are for GPS technology only and shall be used to define the minimally acceptable levels of differential relative positional accuracy required of a Government cadastral survey.

TABLE ONE: **Local Accuracy Standards**

95% Confidence Circle	Application
Less than 0.050 (m)	*Cadastral Project Control*
Less than 0.100 (m)	*Cadastral Measurements*

Local Accuracy (see Appendix A) is an average measure (e.g. mean, median, etc.) of the relative accuracies of the coordinates for a point with respect to other adjacent points at the 95% confidence level.

TABLE TWO: **Network Accuracy Standards**

95% Confidence Circle	Application
Less than 0.100 (m)	*Cadastral Project Control*
Less than 0.200 (m)	*Cadastral Measurements*

The ***Network Accuracy*** (see Appendix A) of all Cadastral Measurements should be reported per the Federal Geographic Data Committee (FGDC) Geospatial Positioning Accuracy Standards to show the relationship of the cadastral survey relative to the National Spatial Reference System.

A least squares adjustment or other multiple baseline data analysis is performed to produce a weighted mean average to verify the required level of positional accuracy has been achieved.

Part Two

Guidelines

The guidelines outlined in this document consist of field data acquisition methods, field survey operations and procedures, data processing and analysis methodologies, and documentation. The use of these guidelines and the manufacturer's specifications provide a means for the surveyor to evaluate the survey and to verify the specified accuracy standard has been achieved.

These guidelines are designed to ensure a survey performed with GPS technology is repeatable, legally defensible and referenced to the ***National Spatial Reference System (NSRS)*** (see Appendix A) by providing the for the following:

- Elimination or reduction of known and potential systematic error sources.
- Occupational (station) and observational (baseline) redundancy to clearly demonstrate the stated accuracy.
- Documentation of baseline processing, data adjustment, and data analysis which demonstrates the recommended procedures and required accuracy.
- Compliance with the Bureau of Land Management Manual of Instructions for the Survey of the Public Lands of the United States, 1973 and state laws.

GPS survey guidelines continually evolve with the advancements in equipment and techniques. Changes to these guidelines are expected as these advancements occur. The size, scope and site conditions of a project may also require variations from these guidelines.

Any variations from these guidelines should be designed to meet the above criteria and to achieve the accuracy standard of the survey as required by this document. All variations shall be documented in the project report.

Section One

Field Data Acquisition Methods

A variety of GPS field data acquisition methods may be used for ***Cadastral Measurements*** (see Appendix A) and ***Cadastral Project Control*** (see Appendix A).

Static Positioning:

Static positioning typically uses a network or multiple baseline approach for positioning. It may consist of multiple receivers, multiple baselines, multiple observational redundancies and multiple sessions. A least squares adjustment of the observations is required. This method provides the highest accuracy achievable and requires the longest observation times.

Static positioning is primarily used for ties to the National Spatial Reference System (NSRS) when observing Cadastral Project Control. This method may also be used for the Cadastral Measurement portion of a cadastral survey.

Fast-Static Positioning:

This method requires shorter occupation times (i.e. 5 to 20+ minutes) than static positioning and may use a radial baseline technique, network technique, or a combination of the two. Fast static requires a least squares adjustment or use of processing software capable of producing a weighted mean average of the observations. Fast-static positioning may be used for observing both the Cadastral Project Control and the Cadastral Measurements of a cadastral survey.

Post-Processed Kinematic (PPK) Positioning:

Post processed kinematic survey methods provide the surveyor with a technique for high production Cadastral Measurements and can be used in areas with minimal obstructions of the satellites. PPK uses significantly reduced observation times compared to static or fast-static observations. This method requires a least squares adjustment or other multiple baseline statistical analysis capable of producing a weighted mean average of the observations. PPK positioning is used for observing the Cadastral Measurements of a cadastral survey.

Real-time Kinematic (RTK) Positioning:

Real-time kinematic positioning is similar to a PPK or a total station radial survey. RTK does not require post-processing of the data to obtain a position solution. This allows for real-time surveying in the field. This method allows the surveyor to make corner moves (stake out) similar to total station/data collector methods. RTK positioning is used for the Cadastral Measurement portion of a Cadastral Survey.

Real-time surveying technology may utilize dual-frequency (L1/L2) techniques for initialization. The subsequent RTK measurements are then accomplished using the L1 carrier phase frequency and are subject to the baseline length limitations of 10km. New RTK measurement technologies can now use the L1/L2 frequencies coupled with improved atmospheric models to determine baseline lengths. This results in longer baselines that can be measured using RTK.

Caution: Operations under a forest canopy using PPK or RTK methods are not recommended. However, these methods are acceptable if they result in a solution, which meets the survey standards. The surveyor must make an informed decision when choosing the appropriate methodology to be used in a particular project area. For survey projects in a forest canopy environment with marginal sky visibility, static, or fast-static GPS methods or even conventional optical methods should be considered in-lieu of using RTK or PPK.

Section Two

Field Survey Operations and Procedures

Field survey operations should be performed using the manufacturer's recommended receiver settings and observation times. Operations under adverse conditions, such as under a forest canopy, may require longer observation times than specified by the manufacturer.

Fixed height or adjustable height antenna tripods/bipods can be used for all rover GPS observations. The elevation of an adjustable height antenna tripod/bipod should be regularly checked to make sure slippage has not occurred.

All plumbing/centering equipment should be periodically checked for proper adjustment.

The following are recommended procedures when using GPS measurement techniques for Cadastral Surveys.

Cadastral Project Control

Cadastral Project Control is the network of the GPS stations, tied to the NSRS, which is surveyed to control all subsequent GPS Cadastral Measurements.

The Cadastral Project Control network shall be established by either static or fast-static survey methods.

The Cadastral Project Control network may be established at the same time the Cadastral Measurements are made. However, the points and resulting baseline vectors used in the Cadastral Project Control network shall be processed to derive the baseline solutions and be adjusted by least squares independently of the observed Cadastral Measurements.

The Cadastral Project Control network is designed to meet the following purposes:

- Provides a framework to reference the survey to a datum, a mapping projection, and the NSRS.
- Supports registration of the Cadastral Measurements into the ***Geographic Coordinate Data Base (GCDB)***.
- Serves as the basis for all subsequent GPS Cadastral Measurements.
- Allows for reporting of the Network Accuracy for the Cadastral Measurements per FGDC Geospatial Positioning Accuracy Standards.
- A well-designed Cadastral Project Control network will offer the surveyor more flexibility for using fast static, kinematic, and RTK survey methods for the Cadastral Measurement portion of a survey. It provides an adequate amount of reference (base) station locations, ties the Cadastral Measurement points together, allows for expanding area of the survey and provides accurate checks throughout survey project.
- The number of stations in the Cadastral Project Control network depends upon factors such as project size, topography, positioning method used, and access. A minimum of two or more

Cadastral Project Control stations should be established as a reference for the Cadastral Measurements.

- All Cadastral Project Control networks should be referenced (tied) to at least two High Accuracy Reference Network (HARN) stations/High Precision Geodetic Network (HPGN) or Continuous Operating Reference Station (CORS) of the NSRS.

- In the absence of HARN/HPGN or CORS stations, other GPS control stations which are referenced to the NSRS and published by or available through other federal, state, or local agencies may be used. The use of such stations shall be evaluated by the surveyor regarding the relationship to the NSRS before inclusion into the Cadastral Project Control network and prior to any Cadastral Measurements occurring.

- The current national reference datum is the North American datum of 1983 (NAD83) of 1986. All control and project information should be referenced to the most current epoch of NAD 83 for example: Wyoming NAD 1983 (1993).

All Cadastral Project Control networks should conform to the following:

- Be referenced to two or more NSRS or other published horizontal control stations, located in two or more quadrants, relative to the cadastral project area.

- Points are established by two or more ***independent baselines*** (see Appendix A).

- Contain loops of a minimum of three baselines.

- Baselines have a fixed integer double difference solution or adhere to the manufacturer's specifications for baseline lengths exceeding the fixed solution criteria.

- All stations in the cadastral project control network should have two or more ***independent occupations*** (see Appendix A).

- The Cadastral Project Control network must be a geometrically closed figure. Therefore, single radial (spur) lines or side shots to a point are not acceptable.

Cadastral Measurements

Cadastral Measurements are the measurements used to define the location of PLSS corners and boundaries. Cadastral Measurements are referenced to the Cadastral Project Control coordinates or by direct ties to the NSRS.

All Cadastral Measurement observations, except RTK, should conform to the following:

- Be constrained to two or more Cadastral Project or NSRS stations which are located in two or more quadrants relative to the cadastral project area.

- Points are established by two or more independent baselines.

- Contain loops of a minimum of three independent baselines.

- Baselines have a fixed integer double difference solution or adhere to the manufacturer's specifications for baseline lengths exceeding the fixed solution criteria.

- Any station pair used as azimuth or bearing reference for use with conventional survey measurements during the course of a cadastral survey should be included in a network or measured with a minimum of two independent vectors using the RTK techniques described below.

- All stations in the cadastral measurements shall have two or more independent occupations.

- Single radial (spur) lines or side shots to a point are not acceptable.

Static Survey Methods

A network or multiple baseline observation scheme should be followed when static survey methods are used to perform a cadastral survey. The procedures should be similar to those outlined in the Cadastral Project Control section of this document or as outlined in the previous section. All corner and control measurements should be included in the final project adjustment.

Fast-static Survey Methods

When using Fast-static methods as the sole measurement method for Cadastral Measurement, then the Cadastral Project Control and the Cadastral Measurements are separate.

One method uses a network or multiple radial baseline approach that utilizes one or more reference (base) receivers, usually two, located in two or more different quadrants and one or more rover receivers with fixed height or adjustable antenna tripods/bipods for Cadastral Measurements. The antenna elevation of adjustable antenna tripods/bipods such be regularly checked during a survey to ensure slippage has not occurred.

Another method uses two or more receivers in traverse or leapfrog observational scheme.

Post-Processed Kinematic (PPK) Survey Methods

When using PPK survey methods, which include stop and go, continuous, leapfrog and other observation schemes as the sole measurement method for Cadastral Measurements, then the Cadastral Measurements and Cadastral Project Control are separate.

This method uses one or more reference (base) receivers usually two located in two or more different quadrants and one or more rover receivers for Cadastral Measurements.

Real-Time Kinematic (RTK) Survey Methods

When using RTK survey methods, as the sole measurement method for Cadastral Measurement, then the Cadastral Project Control and the Cadastral Measurements are separate.

RTK uses a radial style survey scheme with one or more reference (base) receivers and one or more rover receivers for Cadastral Measurements.

The radial nature of RTK requires additional redundant measurements be made as part of the field survey operations and procedures as discussed in these guidelines.

There are four parts of an RTK survey which include:

- System check
- Corner measurements
- RTK calibrations
- Corner moves (stake-out)

RTK System Check

A RTK system check shall be made prior to any RTK Cadastral Measurements.

A RTK system check may also be made at any time during the course of each RTK survey session or at any time the base receiver(s) and rover receiver(s) are setup and initialized per the manufacturer's recommended procedures.

This check is a measurement from the RTK base setup to another Cadastral Project Control station or a previously observed Cadastral Measurement point.

When observing these measurements, the rover will be set to manufacturer's specifications for ***duplicate point tolerance*** (see Appendix A) or less for the measurement of a known point and existing point name.

This check consists of re-observing a known position within the survey. The resulting observed position is then compared by inverse to the previously observed position for the known point. This inverse should be within the manufacturer's recommended values for duplicate point tolerance measurements.

This RTK system check is designed to check the following:

- The correct reference base station is occupied.
- The GPS antenna height is correctly measured and entered at the base and rover.
- The receiver antennas are plumb over station at base and rover.
- The base coordinates are in the correct datum and plane projections are correct.
- The reference base stations or the remote stations have not been disturbed.
- The radio-communication link is working.
- The RTK system is initialized correctly.
- RMS values are within manufacturer's limits.

RTK Corner Measurements

Corner measurements are usually made with RTK using one or more base and one or more rover receiver configurations.

RTK corner measurements shall be made after the system setup check procedures have been completed.

Specified observation times for the highest level of accuracy using RTK for corner measurements as per manufacturer's recommendations are recommended, (for example, 180 seconds of time or when the horizontal (0.02m) and vertical (0.050m) precision has been met for a Trimble kinematic control point).

Under optimal conditions (clear sky, low RMS) a deviation from the manufactures suggested times is appropriate, (for example, a corner may be observed using 30 seconds of time and 20 epochs of measurement data). However, observation times should be set to account for field conditions, measurement methods (i.e. Trimble "topo point" or "kinematic control point") and the type of measurement checks being performed.

Recommended methods for RTK corner measurement:

One method is to observe the unknown point two or more times with the same point name (e.g. 100700) and use a duplicate point tolerance measurement criteria of 2.5 cm. When observing these measurements, the antenna shall be inverted and the receiver reinitialized between observations.

Another method at each found corner location or temporary point (unknown position), two baselines measurements (M1 and M2) are stored to the data collector or receiver for a specified number of seconds or epochs to meet a specified level of precision, (for example, the time requirement for a Trimble kinematic control point) depending upon manufacturer's recommended procedures.

Observation time may be increased due to the constraints of on-the-fly (OTF) post-processing kinematic (i.e. 200+ sec) if the field data is post-processed as a check.

- The antenna should be inverted to force a loss of satellite lock, in between the M1 and M2 measurements, to force the system to reinitialize. The point values resulting from the first baseline measurement is stored and labeled (e.g. 100700M1), and the point resulting from the second baseline measurement is stored and labeled (e.g. 100700M2).

- A field check of the level of accuracy between the measurements may be done by an inverse between M1 and M2. The resulting inverse distance should be less than the Duplicate Point Tolerance of 2.5 cm.

Note: The ***Cadastral Measurement Tolerance*** of 8.6 cm is the maximum acceptable distance for M1 – M2 inverse. It should be accepted only under extremely poor GPS conditions due to tree cover, multi-path, etc. This worst-case condition should only be encountered in the most marginal field conditions for RTK surveys.

The Cadastral Measurement Tolerance value of 8.6 cm is derived from standard error propagation relationships. It is based on the following formula, the square root of the sum of the squares of the Cadastral Measurement Tolerance (8.6 cm) and the maximum allowable error of the Cadastral Project Control (5cm) should approximately equal the maximum allowable error budget of the Cadastral Measurements (10cm).

The baseline measurements (i.e. M1/M2) to the found corner locations or temporary points shall be verified by at least one of the following methods (i.e. static, fast-static, PPK or RTK).

Perform a check measurement (M3) from the same Cadastral Project Control station at a time at least 15 minutes after the M1 and M2 measurements are taken.

An example of one of the many possible observation schemes is described below:

- Using RTK, make a new measurement (M3) to the unknown point (e.g. 100700) from the same base receiver setup separated in time by a minimum of 15 minutes.

Perform a check measurement (M3) from another Cadastral Control Project Station taken either simultaneously with the M1 and M2 measurements or at least 15 minutes after the M1/M2 measurements. An example of one of many possible observation schemes is listed below:

- Using PPK, FS or static, make a new measurement (M3) to the unknown point (e.g. 100700) with the base receiver setup on another Cadastral Project Control station operating simultaneously.

RTK Calibrations

A calibration or site registration is needed in real-time surveying (RTS) in order to relate GPS positions that are measured in terms of the World Geodetic System 1984 (WGS-84) to local grid coordinate projections such as UTM, State Plane Coordinates, or a local North- East- Elevation (NEE) system. Calibrations are not applicable to static or fast-static surveys. A calibration should be used on a project whenever new points are to be staked out. The accuracy of points to be staked out will depend on the accuracy of the calibration.

A calibration is based on a set of points that have 3D coordinates in both WGS-84 and local grid coordinate projection system. The quality of the calibration will be affected by the accuracy and consistency of the GPS coordinates of the points. The Cadastral Project Control points tied to the NSRS should be used as the basis of any calibration.

The number of points that can be used in a calibration is manufacturer and software dependent. Smaller section sized projects may be calibrated with one 3D point. However, for larger several sections to township sized projects four 3D points are recommended. Calibration points should be well distributed around the project exterior.

Projects may be calibrated by two methods: 1) In the field in the data collectors or 2) In the network adjustment and uploaded to the data collector. The later procedure is recommended for large projects.

The calibration computation summary should be examined for reasonable results in the horizontal scale, maximum vertical adjustment inclination, and the maximum horizontal and vertical residuals. The RTK System Check can be used to verify the accuracy of the calibration.

RTK Corner Moves (stakeout)

RTK technology allows the surveyor to make a corner move or stakeout from a known position to an unknown (calculated) position relative to the controlling corners for a PLSS survey or resurvey.

The system check may be done at any time during the survey to detect for blunders and the initialization quality of the survey prior to making any RTK observation for Cadastral Measurements and prior to making any corner moves.

Note: Caution should be exercised when using grid coordinates for stakeout. It is important to insure the appropriate corrections for convergence, elevation and distance are accounted for relative to the rules of the PLSS.

To make a corner move using RTK the following is a recommended procedure:

- Navigate to the calculated corner location (e.g. 140700CP) using coordinates. For example, navigate "from" station number (100700) and "to" station number (140700CP).

- Take a measurement (e.g. 140700M1), inverse between M1 and compare to the calculated position (e.g. 140700CP) and move the remaining distance and direction to the true (calculated) location as necessary. Repeat as required until satisfied you are at the position then store M1 and overwrite previously stored point.

- Force loss of satellite lock and initialization by inverting the rover antenna. Reinitialize and take another measurement (e.g. 140700M2) and store.

- Inverse between the measured one (140700M1) and the measured (140700M2). If the measured positions (M1 and M2) are within the duplicate point tolerance of the calculated position then the initializations and measurements are correct. Note, these M1 and M2 measurements are of a shorter duration (30 seconds).

- Set the monument at the true corner location.

- Take a measurement on the set monument (e.g. for 180 seconds) and store the position with a different name (e.g. 140700). Optionally, set the receiver or data collector to store data for subsequent post-processing.

- As a check, inverse from the stored position (e.g. 140700) to the calculated corner position to determine the set true corner location, next inverse to the controlling corners and check the bearing and distance to insure the correct procedures were followed. The established corner location should be within the defined local spatial accuracy standards required of the survey.

Section Three

Data Processing and Data Analysis

All data processing (baseline solutions) and data analysis (least squares or weighted mean average) shall follow the manufacturer's recommended procedures.

A double difference fixed integer solution is required for all cadastral measurements regardless of the positioning technique used.

Project Control network shall be processed to derive the baseline solutions and be adjusted by least squares independently of the observed Cadastral Measurements.

When integrating GPS observations into conventional terrestrial survey procedures it is imperative the surveyor verify the following:

- The State Plane or local plane horizontal scale factors, angular rotation factors, zone and units of measure are applied correctly.

- The combined scale factors for elevation, to determine ground distance at project elevation or an average project elevation are applied correctly.
- The appropriate datum has been used.
- A check to insure no hidden transformation or double transformations of the data has occurred.
- If using GPS with terrestrial data, then a check (e.g. measure the distance between two known points with an EDM) should be done to insure the computation of the combined scale factors are correct. This is done to insure the ***ground distance*** (see Appendix A) is appropriate.
- A check to insure the computation and reporting of basis of bearing are appropriate.

Section Four

Project Documentation

The use of GPS surveying methods to establish geodetic Project Cadastral Control and/or Cadastral Measurements for survey and resurvey of Public Lands is considered the practice of Professional Land Surveying in all states. Therefore, all GPS surveying projects must be performed under responsible charge of a federally authorized Surveyor or a Professional Land Surveyor licensed to practice Land Surveying in the applicable state.

A surveyor's narrative report shall be prepared and submitted to the Group (Project) File by the surveyor in responsible charge as documentation of the successful completion of the land survey or cadastral survey project.

A surveyor's narrative report should include:

- Make and Model of the GPS receiver, Antenna, and related equipment.
- A processing generated report or summary of all RTK field operations, including calibrations, duplicate point measurements.
- A processing generated report regarding the baseline processing results and the software and version number used.
- A processing generated report regarding the Network adjustment results including a summary of covariance's, standard deviation or RMS values and the software and version number used.
- A network diagram, true line diagram or map showing the network configuration as designed.
- A list of the HARN, CORS or reference stations used in the survey.
- A list of coordinates by station including the datum, geoid model, epoch, and measurement units used.
- Local and Network Accuracies.

- A GMM .LZH file for inclusion into GCDB.
- Document any variations from these guidelines.

Reporting bearings and Distances:

A Basis of Bearing for a Government Cadastral Survey, when using GPS technology shall be expressed as "Geodetic Bearing or Azimuth". This bearing or azimuth shall be determined at the midpoint of the observed line as the "mean" between the Normal Section Forward Azimuth (NSFA) and the Normal Section Back Azimuth (NSBA) between points.

All ground distances shall be determined at ground elevation, except where the requirements are for sea level, using the appropriate geoid model to determine the geoid separation. For a cadastral survey, the height above the geoid and the orthometric height shall be considered the same.

Appendix A

DEFINITIONS

Cadastral Project Control is the network of the GPS baselines tied to the NSRS, which is surveyed to control all subsequent GPS Cadastral Measurements. The Project Control is adjusted independently of other cadastral measurements.

Cadastral Measurement Tolerance is the maximum acceptable distance for inverse between two measurements to the same point. This value is 8.6 cm. When measurements are made within this tolerance in an RTK survey the two observations may be recorded as the same point number. These redundant measurements can then be included in a least squares or multi-baseline analysis. This worst-case condition should only be encountered in the most marginal field conditions for RTK surveys. These points should be noted in the surveyor's narrative report.

The Cadastral Measurement Tolerance value of 8.6 cm is derived from standard error propagation relationships. It is based on the following formula, the square root of the sum of the squares of the Cadastral Measurement Tolerance (8.6 cm) and the maximum allowable error of the Cadastral Project Control (5cm) should approximately equal the maximum allowable error budget of the Cadastral Measurements (10cm).

Cadastral Measurements are the measurements used to define the location of *Public Land Survey System (PLSS)* corners and boundaries. Cadastral Measurements are based on the Cadastral Project Control coordinates or direct ties to the NSRS.

Duplicate Point Tolerance is the maximum distance in an RTK system setup check that two observations of the same point can differ by. It also the maximum distance in an RTK survey that two observations of the same point can differ by and still be recorded as the same point for least squares or multi-baseline analysis. The duplicate point tolerance for these guidelines is 2.5 cm.

The **Geographic Coordinate Data Base (GCDB)** is a database containing geographic coordinates, and their associated attributes, for all corners of the Public Land Survey System.

Ground distance is the horizontal distance measured at the mean elevation between two points.

Independent Baselines (Non-Trivial): For each observing session there are n-1 independent baselines where n is the number of receivers collecting data simultaneously during a session.

Independent Occupations: Two or more independent occupations for the stations of a network are specified to help detect instrument and operator errors. Operator errors include those caused by antenna centering and height offset blunders. When a station is occupied during two or more sessions, back-to-back, the antenna pole or tripod will be reset and plumbed between sessions to meet the criteria for an independent occupation.

Local Accuracy, as defined in Part 2, Standards for Geodetic Networks, FGDC Geospatial Positioning Accuracy Standards, is an average measure (e.g. mean, median, etc.) of the relative accuracies of the coordinates for a point with respect to other adjacent points at the 95% confidence level. For horizontal coordinate accuracy, the local accuracy is computed using an average of the radii of the 95% relative confidence circles between the point in question and other adjacent points. This indicates how accurately a point is positioned with respect to other adjacent points in the local network. Based upon computed relative accuracies, local accuracy provides practical information for users conducting local surveys between control monuments of known position. Local accuracy is dependent upon the positioning method used to establish a point. If very precise instruments and techniques are used, the relative and local accuracies related to the point will be very good.

The reported Local Accuracy for cadastral survey purposes will be computed from the error ellipses generated by a least squares or other multiple baseline statistical analysis, which is fully constrained to the Cadastral Project Control.

National Spatial Reference System (NSRS) is defined and managed by the National Geodetic Survey (NGS). It is a consistent national coordinate system that specifies latitude, longitude, height, scale, gravity, and orientation throughout the Nation, as well as how these values change with time. NSRS consists of the following components:

- The National CORS, a set of Global Positioning System Continuously Operating Reference Stations meeting NOAA geodetic standards for installation, operation, and data distribution;.
- A network of permanently marked points including the Federal Base Network (FBN), the Cooperative Base Network (CBN), and the User Densification Network (UDN).
- A set of accurate models describing dynamic geophysical processes affecting spatial measurements.
- High Accuracy Reference Network or High Precision Geodetic Network stations established by GPS observations.
- Vertical control marks, which define elevation and are referenced to NGVD 29 or NAVD 88.
- All other horizontal and vertical marks established to define the NSRS.

NSRS provides a highly accurate, precise, and consistent geographic reference framework throughout the United States. Stations or marks established by GPS or High order levels should be used with GPS survey projects.

Network Accuracy is the absolute accuracy of the coordinates for a point at the 95% confidence level, with respect to the defined reference system. Network accuracy can be computed for any positioning project that is connected to the National Spatial Reference System (NSRS).

The network accuracy of a control point is a number, expressed in centimeters, that represents the uncertainty in the coordinates, at the 95% confidence level, of this control point with respects to the geodetic datum. For NSRS network accuracy classification, the datum is expressed by the geodetic Values at the Continuously Operated Reference Site (CORS) supported by National Geodetic Survey (NGS). By this definition, the local and network accuracy values at CORS sites are considered to be infinitesimal, i.e., to approach zero.

Network accuracy for cadastral survey reporting purposes will be computed from the error ellipses generated in a least squares adjustment fully constrained to CORS or HARN stations or other GPS control stations which are referenced to the HARN or CORS as outlined in the Cadastral Project Control portion of this document.

APPENDIX B

COMPUTATION OF ACCURACIES

The local accuracies of the PLSS corners are based upon the results of a least squares adjustment of the survey observations used to establish their positions. They can be computed from elements of a covariance matrix of the adjusted parameters, where the known NSRS control coordinate values have been weighted using their one-sigma network accuracies.

95% Confidence Circle

The 95% confidence circle representing a local accuracy can be derived from the major and minor semi-axes of the standard relative ellipse between two selected points. The 95% confidence circle is closely approximated from the major (a) and minor (b) semi-axis parameters of the standard ellipse and a set of coefficients. For circular error ellipses, the circle coincides with the ellipse. For elongated error ellipses, the radius of the circle will be slightly shorter than the major semi-axis of the ellipse. The radius r of the 95% confidence circle is approximated by:

$r = K_p\, a$

Where

$K_p = 1.960790 + 0.004071\ C + 0.114276\ C^2 + 0.371625\ C^3,$

$C = b/a.$

Note that the coefficients in the above expression are specific to the 95% confidence level, such that when the major semi-axis of the standard ellipse is multiplied by the value of K_p, the radius of the 95% confidence circle is obtained directly, and no further conversion is required.

Appendix C

References

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